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IDENTIFICATION OF PLASTICS USED IN NAVAL ORDNANCE

QUALITY EVALUATION LABORATORY

NAVAL TORPEDO STATION

KEYPORT, WASHINGTON 98345

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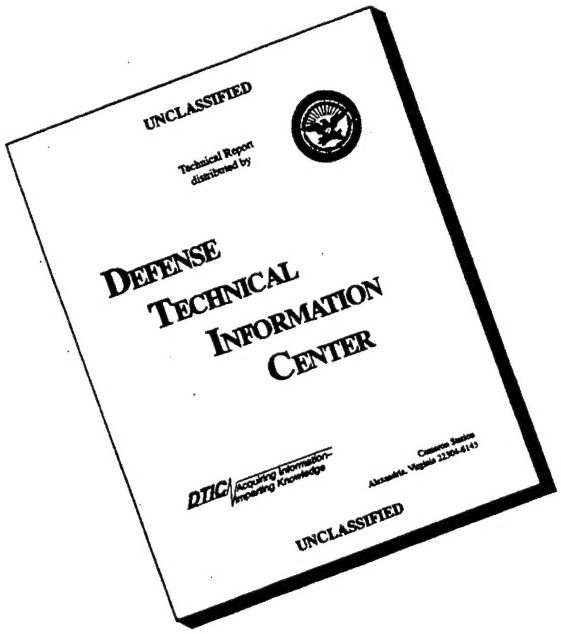

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IDENTIFICATION OF PLASTICS USED IN NAVAL ORDNANCE

ABSTRACT

1. The Naval Torpedo Station, Keyport, Washington, was assigned responsibility for conducting a continuing program of plastics identification by BUWEPS Instruction 5450.4 of 24 March 1960.

2. Tests are described for identifying plastics commonly found in Naval ordnance weapons. The tests require relatively simple test procedures and equipment. Identification tests described are sensory, burning, chemical, and infrared spectroscopic tests. Typical spectrograms are included.

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By direction

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Report No. QE/K 67-83

QUALITY EVALUATION LABORATORY
Keyport, Washington

IDENTIFICATION OF PLASTICS USED IN NAVAL ORDNANCE

INTRODUCTION

Identification of plastics is essential in the evaluation and quality control of Naval ordnance weapons primarily to assure that a particular plastic required by a specification has been used by the manufacturer. The identification problem has been compounded in recent years by the sharp rise in the number and varieties of plastics used in ordnance. The problem is further increased because many of these plastics closely resemble each other, at least superficially; and for certain applications, may be used more or less interchangeably.

These developments have made it necessary to find plastic identification methods that are rapid, simple, and reliable, and that require a minimum of laboratory test equipment. While there are a variety of techniques available for identifying plastics, no single method has proven entirely satisfactory for furnishing positive proof of the identity of a plastic. A general rule is that the findings derived from one identification test should always be confirmed by additional tests.

A comparative study was made of methods for identifying plastics frequently found in Naval ordnance items to determine the simplest and most effective of these for meeting specific problems of plastics identification. This study was made by the Quality Evaluation Laboratory of the Naval Torpedo Station, Keyport, Washington, under responsibilities delegated to it by the Naval Ordnance Systems Command to conduct a continuing program of plastics identification and evaluation.

It is an assumption in this report that the reader already has a general understanding and familiarity with plastics, chemistry, and laboratory test procedures. In the final analysis, the proof of a plastic's identity rests on the skill, knowledge, and ingenuity of a trained and experienced examiner.

The findings presented in this report are intended primarily for Naval chemical laboratories having comparatively limited test facilities, and the identification tests recommended are those that require relatively simple test procedures and equipment. It is stressed that this report is designed to serve as a general guide to plastics identification and not as a complete and comprehensive review of the field. For this reason specific and detailed supplementary information is cited from a number of other sources, but is not incorporated.

The identification tests described in this report are presented in the order of their increasing complexity. The sequence in which they are discussed is as follows: (1) sensory tests, (2) burning tests, (3) chemical tests, and (4) infrared spectroscopic tests. An important adjunct to the report is enclosure (1), a collection of plastics samples frequently used in the manufacture of Naval Ordnance which is intended to assist in several of the identification tests.

SENSORY TESTS

The first step in identifying a plastic is a gross, or overall, examination of the sample in which the examiner uses his senses of sight, smell, and touch. While a comparatively simple procedure, this initial examination should not be neglected and is essential in narrowing the number of possible plastics to be considered. Clues such as the appearance, feel, and odor of the sample are all important factors, and may be sufficient for an experienced examiner to tentatively identify the plastic with reasonable certainty. However, it should be remembered that a sensory examination alone is not a basis for making a positive identification and findings should always be verified by further, more extensive testing.

At this point a note of caution is in order. Plastic parts which have been irradiated with gamma rays, electron beams, and other radiation sources may change in appearance and feel which may mislead the examiner.

The sensory test, then, will usually greatly lessen the work required in the confirming testing that follows. For example, an observation that the sample is colorless and clear would indicate that the plastic is not a phenolic, melamine, urea-formaldehyde, nylon, Teflon, acetal, polyethylene (unless in very thin film), polypropylene, polyurethane, silicone, acrylonitrile-butadiane-styrene (ABS), neoprene, or Thiokol, and, thus, the field of investigation would be greatly narrowed.

Since many of the factors of importance in the sensory examination are difficult to describe or define, and, in fact, must be experienced first hand, the set of plastics samples (enclosure (1)) will be helpful in familiarizing the examiner with these identifying characteristics.

Several plastics that can be more readily identified through sensory observation are described as follows: Phenolics generally can be identified by their characteristic odor generated by rubbing, heating, or filing. Teflon has a firm very slippery surface and is generally white or milky in appearance. This milky appearance disappears sharply when the sample is heated and reappears just as sharply when it has cooled. Nylon often can be identified by an

experienced examiner without his being able to state the basis for his identification other than characteristic feel and appearance which cannot be accurately described. A number of the newer plastics resemble nylon and for this reason any preliminary identification should be verified by additional tests. Acrylics are frequently marketed in transparent sheet form. This, combined with their characteristic odor developed on heating or rubbing, will identify them. High-pressure polyethylene has a waxy, soft surface which is easily scratched. Generally, this characteristic is sufficient to identify it but, again, confirming tests should be made. Acetal has a visual appearance which, while quite characteristic and difficult to describe, might best be described as flour-like. This appearance, together with its unique burning characteristics (a clear, blue flame like burning alcohol), identifies it. Silicone elastomers have a characteristic soft surface feel. Here again, burning the material serves as a confirming test, yielding a white ash that glows brightly while burning.

Thermoplastics are distinguished from thermosetting plastics by a procedure which, while not strictly a burning test, does involve heating the plastic. A heated soldering iron (heated to below its operating temperature, about 200° to 220° C) is pressed against the sample: if the iron sinks into the sample it is thermoplastic; if the iron does not sink into the sample it is thermosetting.

BURNING TESTS

In the preceding discussion, burning tests are mentioned as an effective means for verifying the results of sensory tests. Although one of the simplest and most useful methods of identifying plastics, burning tests require considerable experience on the part of the examiner. The samples of known plastics (enclosure (1)) should be tested by burning and the effects carefully noted. Appendix A is a table which lists the plastic samples included in enclosure (1).

In many cases, brand names have been used on the sample labels in enclosure (1) because they are simpler and better known. This table gives the label name, the chemical name, and a description of the specimen.

The burning test requires little equipment, usually an alcohol lamp, Bunsen burner, or similar burner giving a nonluminous flame, a pair of tweezers, and a length of copper wire. The copper wire is used to distinguish between those plastics which contain halogens, usually chlorine, and those that do not. The wire is heated to a red heat, touched to a sample of the plastic, and then returned to the flame. A green flame indicates a halogen. This test does not give a positive result with fluorine compounds such as Teflon, but is positive with chlorine, bromine, or iodine compounds.

The chart (Appendix B), originally published in the Modern Plastics Encyclopedia Issue for 1960[1], is a more complete guide for using burning tests, and furnishes specific criteria required in burning tests. Additions have been made to this chart to incorporate some of the newer plastics used in ordnance manufacture.

The following describes the general effects of burning plastics to be observed in making an identification. The chart (Appendix B) should be referred to for specific identification. To perform a burning test, a small sample of the material to be identified is held with tweezers in the flame. The ease of ignition, reaction to the heat of the flame (does the sample melt, swell, etc.), and characteristics of the flame and smoke are noted. The sample is then removed from the flame and subsequent results observed (does the flame extinguish itself, what type of ash is left, etc.). It should be emphasized here that if the sample material is not self-extinguishing, the flame should be blown out and the odor noted with caution. That is, one should be careful when smelling the fumes from a burned plastic because some are either toxic or highly irritating. Many of the odors generated by burning plastics can only be described as "characteristic" and for this reason must be experienced by the examiner while comparing them to the odors of the known samples.

In certain cases, great care must be used in interpreting the burning test. If the plastic contains appreciable amounts of plasticizers or fillers, the burning characteristics of these additives may give misleading indications. For example, any soft, flexible plastic which cannot be readily identified as one of the standard elastomers should be suspected of containing plasticizers. These plastics can be identified by burning tests after the additive has been extracted with a solvent such as petroleum ether. If the sample hardens after extracting the additive, the presence of a plasticizer may be considered as confirmed. The remaining plastic can then be identified by a burning test.

CHEMICAL TESTS

In some cases a burning test alone does not provide positive identification, and may only narrow the search to a few plastics. In this event, the plastic may be more positively identified by chemical tests. For example, it may be difficult to distinguish between cellulose acetate, cellulose acetate butyrate, and cellulose acetate propionate by a burning test. The identification can be extended by placing a sample of the plastic overnight in a 20% solution of sodium hydroxide. When the solution is acidified with sulfuric acid, the characteristic odor of

[1]Modern Plastics Encyclopedia Issue for 1960, Volume 37 Number 1A, Bristol, Connecticut, McGraw-Hill, Inc., September 1959

the particular organic acid that results is noted. If necessary, the organic acid can be distilled off and identified by further chemical tests.

Another set of plastics difficult to distinguish by a burning test is urea-formaldehyde and melamine-formaldehyde. While these two plastics are readily differentiated from practically all other known plastics by their burning characteristics (non-melting with a characteristic odor) they are difficult to distinguish from each other. Several tests are available which will identify the two. The first relies on the superior resistance of melamine-formaldehyde to weak acids. The sample is boiled for several minutes in 1% sulfuric acid. After 10 minutes of boiling, melamine-formaldehyde remains unattacked, while the urea-formaldehyde shows signs of attack (a frosted surface). A second test may be made by refluxing some of the ground resin in 100 milliliters of 3N · hydrochloric acid using a fractionating distilling column as a condenser. If the plastic is melamine-formaldehyde, a white sublimate of melamine-hydrochloride will collect in the lower bulb of the condenser and be washed back into the flask.[2,3]

High- and low-density polyethylene and polypropylene can be distinguished from each other by means of a simple density test. The density of an alcohol-water solution is adjusted until one plastic just floats and the other (higher density) sinks. The specific gravity of the solution can be readily measured and the density of the plastic deduced.

Differential thermal analysis (DTA) is another technique which may be useful in identifying polymers. By DTA it is possible to detect

[2]A useful guide to chemical identification tests has been published in Modern Plastics Encyclopedia 1966, Volume 43 Number 1A, Bristol, Conn., McGraw-Hill, Inc., September 1965 (pages 34 through 38). Reprints can be ordered from Modern Plastics, Reprint Department, 1301 Avenue of the Americas, New York, N.Y., 10019. The test procedures described are considerably more elaborate than burning tests, but are more positive. The tests are divided into three series: The first is based on a series of solubility tests; the second is based on sodium fusion followed by tests for sulphur, nitrogen, phosphorus, chlorine, and fluorine; and the third consists of specific tests for individual plastics which may have been indicated by the two previous tests. This latter series can be used to separate similar plastics, such as methacrylate and acrylate, which are difficult to distinguish by burning tests alone.

[3]Another recommended source for chemical identification tests is The Identification of Plastics and Rubbers, K. J. Saunders, London, England, Chapman and Hall Ltd., 1966.

differences in polyethylene that may be due to molecular weight distribution, thermal history, etc. However, not enough information is available for this to be a positive method for identification.

INFRARED SPECTROSCOPIC TESTS

Infrared spectroscopy is perhaps the most positive method of identifying plastics. Some plastic samples can be tested as received without any preparation if they are already in film form. A thin film can be placed directly into the sample beam of the spectrophotometer and its infrared spectrum recorded. If the sample is a thick film, a sheet, or a coating on a sheet of material, the multiple internal reflection technique can be used.

If the plastic cannot be tested directly, some form of sample preparation is necessary. Films can be prepared by dissolving the plastic in a suitable solvent; or if the sample is thermoplastic a film may be pressed at elevated temperature. Another method of preparation relies on pyrolysis of the plastic, followed by infrared inspection of the pyrolyzate. For some samples it may be necessary to grind the material into small particles and then use the Nujol mull or potassium bromide pellet technique.

Before discussing sample preparation methods in greater detail, it is emphasized that it is highly desirable that a file of infrared spectrophotograms of known plastics be compiled. Once such a file is compiled, many plastics can be easily identified. The Quality Evaluation Laboratory at Keyport has many of these infrared spectra and will prepare and supply copies on request. In general, however, it is believed more satisfactory for each laboratory to prepare its own spectra using known materials. Other sources of infrared spectra of plastics are listed in Appendix C.

Plastic samples for which a solvent can be found can be cast into a film suitable for infrared spectrographic analysis. Finding a solvent is largely a matter of trial and error; however, the solubility data in the Modern Plastics Encyclopedia for 1966 identification method is helpful. The solvent chosen should have only moderate volatility to avoid "blushing" in the film, but it must have sufficient volatility to allow it to be readily removed from the film. Some plastics are excellent film formers and films cast from these can easily be stripped from the surface they are cast on (such as a glass slide) and transferred to a sample carrier for placing in the sample beam of the infrared spectrophotometer.

On the other hand, some plastics form such weak films that the film cannot readily be stripped. For such plastics the simplest procedure is to cast the film directly on a sodium chloride crystal. One precaution

to be observed in this procedure is that the solvent must be completely removed from the film. Another precaution is that certain plastics such as the polycarbonates have a strong tendency to absorb moisture from the air and this must be guarded against. It should be noted that it is often possible to obtain a clear plastic film from a plastic which has been filled with opaque materials, since the fillers often settle out of the solution. A list of plastics solvents and a file of infrared spectra are available from the Dow Chemical Company by Richard A. Nyquist.[4]

A plastic sample may contain one or more additives in addition to the basic resin. Plasticizers, fillers, stabilizers, antistatic additives, etc., all have characteristic absorption patterns which may interfere with the identification of the plastic. However, this can be improved somewhat by extracting a sample of the material with a solvent such as petroleum ether. The residual plastic can then be identified by making a film as described above. A useful variation, especially if the original sample is a film, is to evaporate the solvent which contains the plasticizer and put the residual plasticizer in the reference beam of the spectrometer, while the original sample film is placed in the sample beam. When properly done, only the absorption bands of the materials not soluble in the extractant will appear in the resulting spectrogram. If the extractant is properly chosen the spectrogram will be that of the plastic. A file of infrared spectra for additives and plasticizers is available from the Dow Chemical Company by Russell B. DuVall.[5]

If the sample is thermoplastic it may be possible to press a film from it while it is heated. A useful method is found in the article by Coakley and Berry.[6] The equipment required consists of a hot plate, a laboratory press, and two flat polished hard steel discs. To make the film, the discs are placed on the heated hot plate with the thermoplastic sample on one of the discs. When the plastic has reached its softening point the second disc is placed on top of the sample. The mold containing the sample is transferred to the press and pressed at about 15,000 pounds. The film is allowed to cool under pressure in the mold.

A simpler variation of the above is to use a laboratory press equipped with hot plates that have thermostatic controls. After the

[4]Nyquist, Richard A., Infrared Spectra of Plastics and Resins, Second Edition, The Dow Chemical Co., Midland, Mich., 1961
[5]DuVall, Russell B., Infrared Spectra of Plasticizers and Other Additives, The Dow Chemical Co., Midland, Mich., 1962
[6]Coakley, J. E., and Berry, H. H., "Pressed Film Technique for Obtaining Infrared Spectra of Thermoplastic Materials," Applied Spectroscopy, Volume 20 Number 6, November-December 1966

hot plates have reached the desired temperature the polished steel discs with the sample between them are placed between the hot plates, and then pressed at 12,000 to 15,000 pounds for 2 or 3 minutes. The discs may be removed and allowed to cool. If the film sticks to the discs it may be necessary to pretreat them with a parting agent such as a heat-resistant silicone fluid, which must be subsequently removed. A film of polyvinyl alcohol or some other plastic film may serve as a parting agent.

The above methods apply to plastics which can be easily dissolved or which may be pressed into a film. For other materials the pyrolysis technique may be useful.

The simplest method is to place a sample of the material in a 15 by 85 mm test tube and heat the lower end of the tube strongly in a Bunsen burner. If the tube is held nearly horizontally, the pyrolyzate will collect in the upper end of the tube and can be transferred to a sodium chloride crystal as a "smear". If needed a second crystal can then be placed on top of the pyrolyzate to form a sandwich. The pyrolyzate may be dissolved in carbon tetrachloride or carbon disulfide and then handled as a liquid sample. While this method will give identical spectrograms with identical samples, it will not always give the same spectrogram with different samples of the same generic type of plastic. Thus, pyrolyzates from different polyurethanes, for instance, may have spectrograms with relatively little in common. For this reason this method can be used for positive identification only if the spectrogram compares with a spectrogram from a known material; otherwise, it is difficult to use.

With certain materials, such as melamine, Mylar, ureas, and some others, pyrolyzates are solids or are difficult to obtain. Such pyrolyzates are better obtained using an instrument such as the Barnes Pyrolyzer in which the pyrolyzate is collected directly on the sodium crystal with no need for transfer. Figure 1 is such a spectrogram.

For samples which cannot be made into films or do not form suitable pyrolyzates, it may be necessary to grind the polymer into small particles and then obtain the infrared spectrum by means of the Nujol mull or potassium bromide pellet techniques.

If the plastic is sufficiently brittle it can be filed or scraped. Rubbery polymers may sometimes be ground by first freezing them with dry ice or liquid nitrogen. Sometimes solvents (like hot toluene) can help in breaking up samples into small particles. The small particles can be mixed with potassium bromide (on the order of 1 to 100) before making the pellet, or the particles may instead be mulled with Nujol or Fluorolube.

A group of spectrograms is included with this report to illustrate some of the problems involved. For instance, figures 2, 3, and 4 are spectrograms from three urethanes which demonstrate differences found between similar plastics. The N=C=O band at 4.4 microns and the band at 4.7 microns (figure 3) appear in some but not others. Similar problems with polyamides are illustrated by figures 5 and 6. Both charts were made from pyrolyzate smears but the Nylon 6/6 (figure 5) has fairly broad peaks at 10.1 and 11.0 microns which do not appear in the Capran curve (figure 6). Also the latter chart has several sharp peaks at 8.9, 9.2, 10.2, 10.5, 11.2, 11.5, and 12.2 microns which are not seen in figure 5.

Figures 7 through 19 are typical spectrograms obtained from smears of pyrolyzates of various plastics. Figures 20 through 25 are typical spectrograms of films formed from solutions of various plastics; and figures 26 through 29 are spectrograms of plastic films as manufactured. Figure 26 also demonstrates the formation of prominent interference bands in the 2- to 7-micron region.

The fact that the infrared absorption curve obtained from a pyrolyzate is often quite different from that obtained from the original plastic is demonstrated by figures 30, 31, 32, and 33. The first shows the difference between cellulose acetate and its pyrolyzate. The plastic gives two separate peaks at 2.85 and 3.4 microns while the pyrolyzate combines these into a broad peak. Also the cellulose acetate gives three equal peaks at 12.5, 13.3, and 14.1 microns but the pyrolyzate gives only the peak near 13.3 microns. In the case of Lucite (figure 31) the original material gives peaks at 8.0, 8.7, 10.2 and 10.4 microns while the pyrolyzate does not. On the other hand a peak at 3.0 microns is much stronger in the pyrolyzate curve. In figure 32 the original polyvinyl chloride has strong absorption bands at 7.0, 7.5, 8.0, 9.1, and 10.5 microns which the pyrolyzate does not have. Figure 33 shows the difference between a polyamide film, Capran, and its pyrolyzate. The pyrolyzate gives peaks at 7.5, 10.2, 10.5, 11.2, 11.5, and 12.2 microns which the film does not have. In some cases the original material has a more complex spectrum but in other cases the reverse is true.

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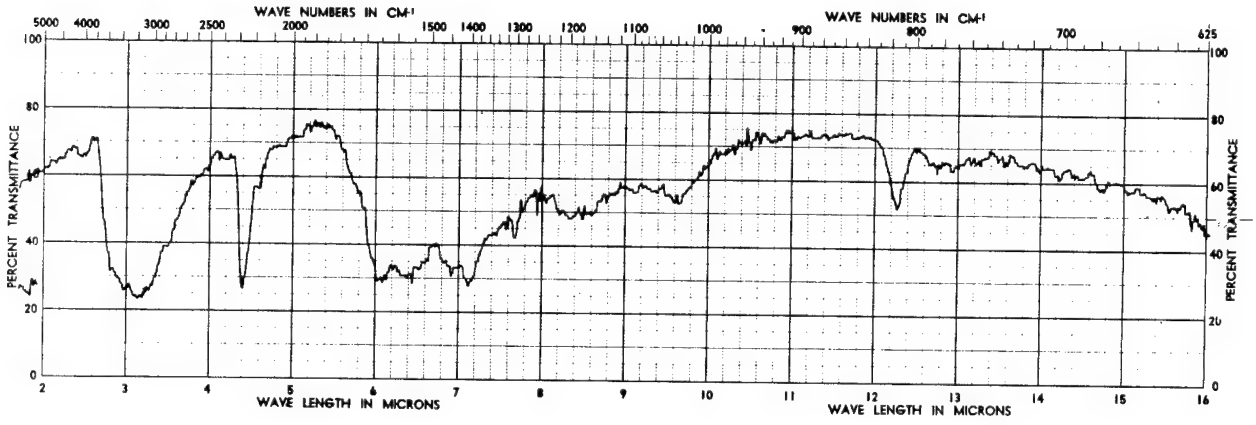


Figure 1. Melamine-formaldehyde pyrolyzate - Barnes pyrolyzer

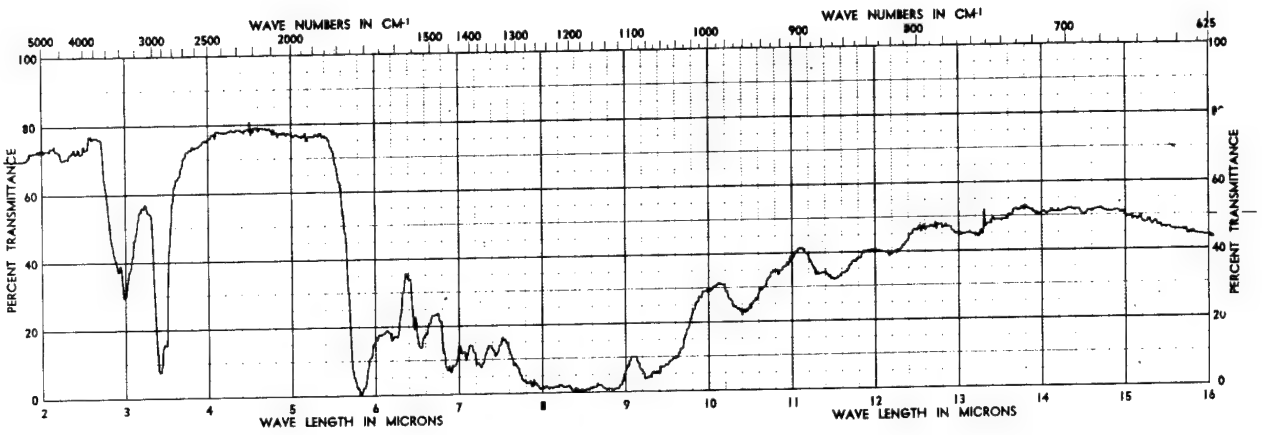


Figure 2. Polyurethane foam (flexible) pyrolyzate

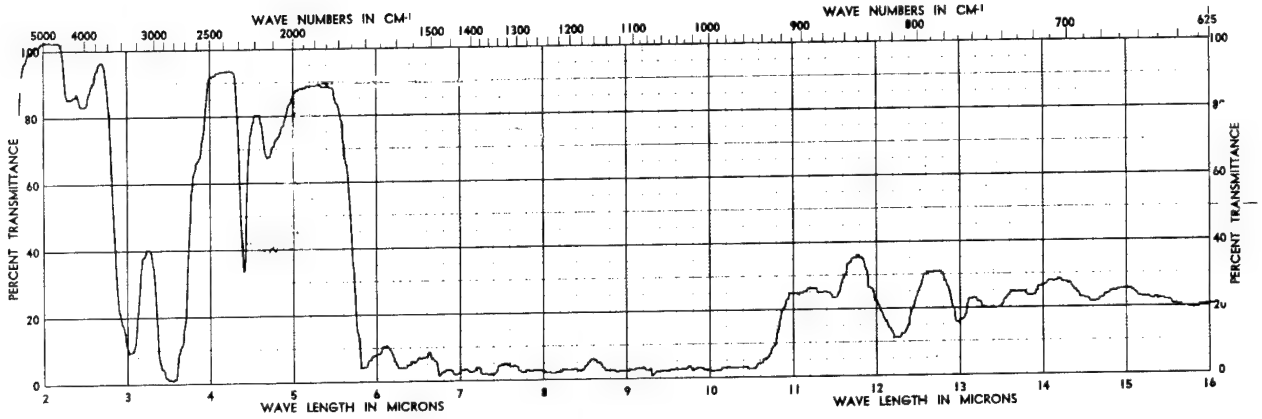


Figure 3. Urethane polymer (elastomer) pyrolyzate

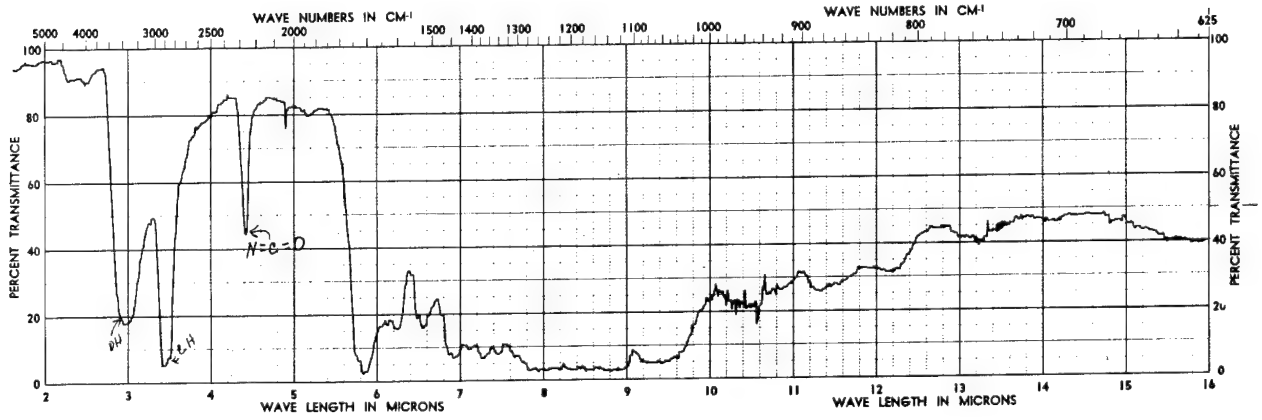


Figure 4. Polyurethane foam (soft) pyrolyzate

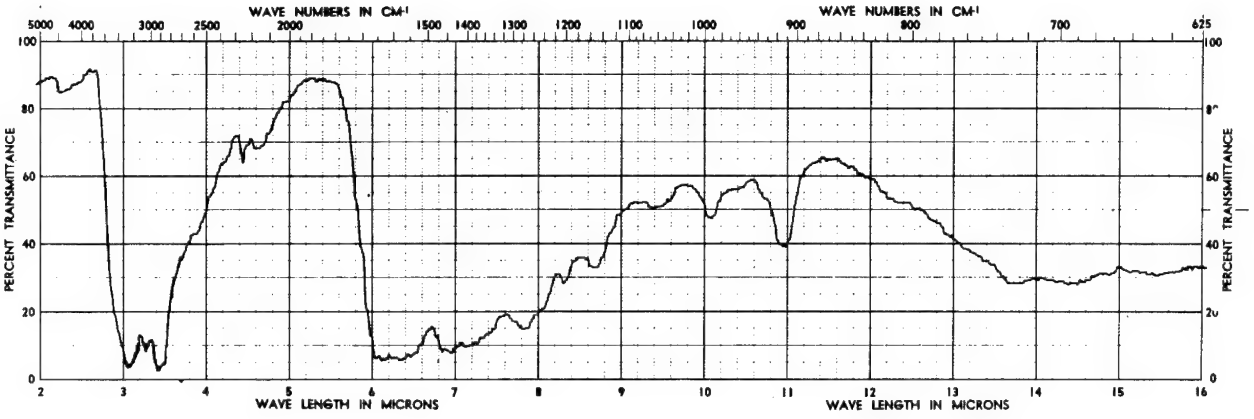


Figure 5. Nylon 6/6 pyrolyzate

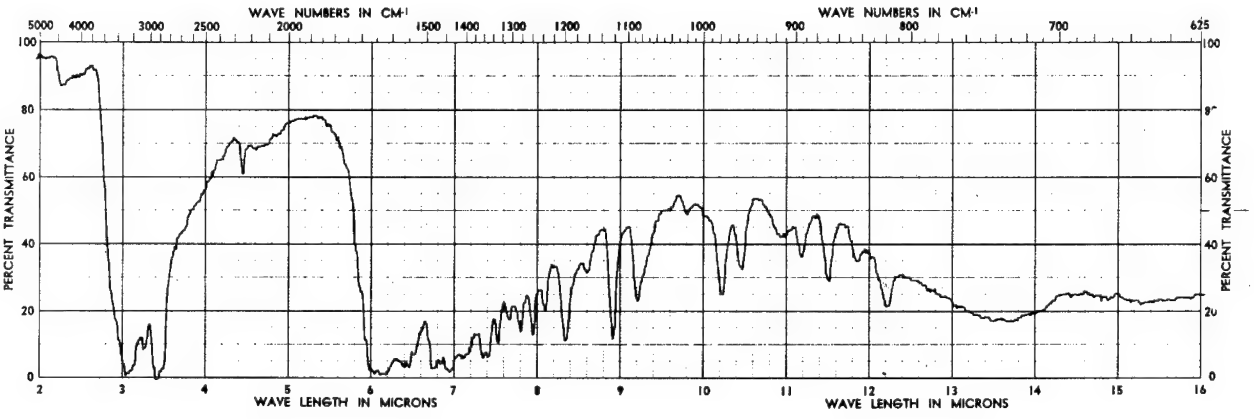


Figure 6. Polyamide film ("Capran") pyrolyzate

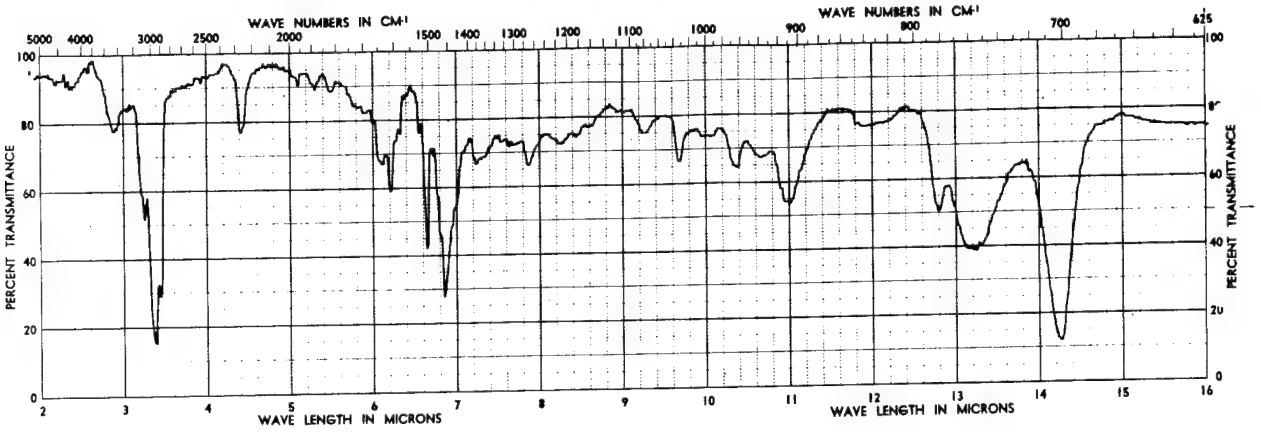


Figure 7. ABS pyrolyzate

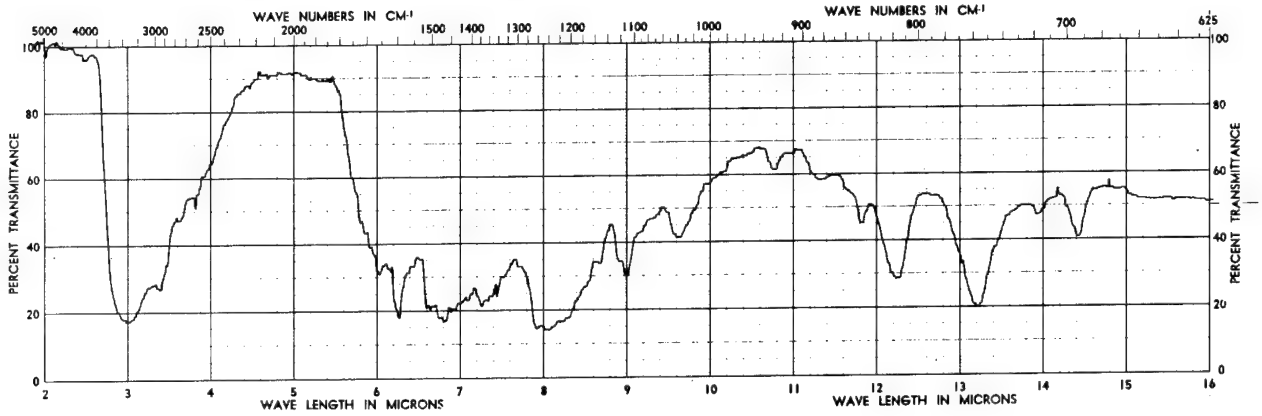


Figure 8. Phenolic pyrolyzate

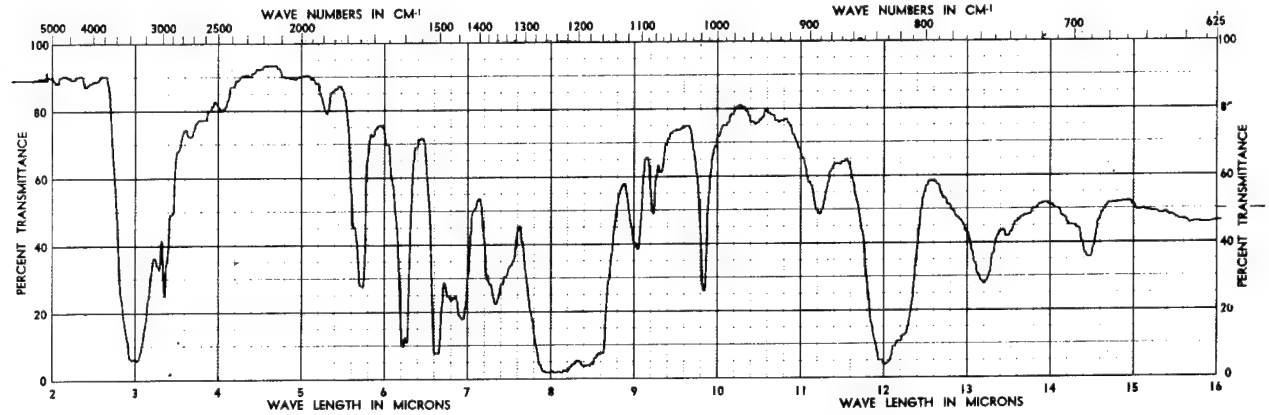


Figure 9. Polycarbonate pyrolyzate

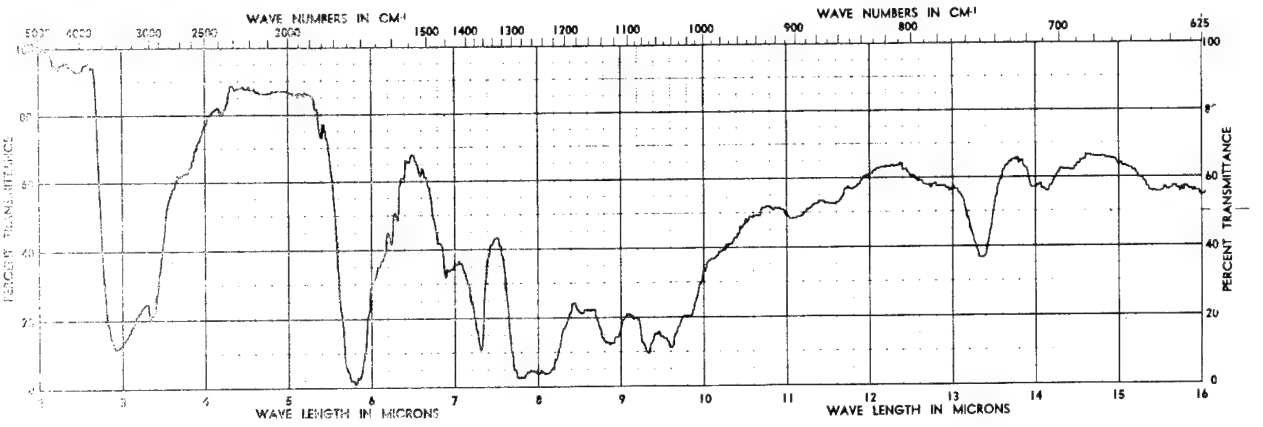


Figure 10. Cellulose acetate pyrolyzate

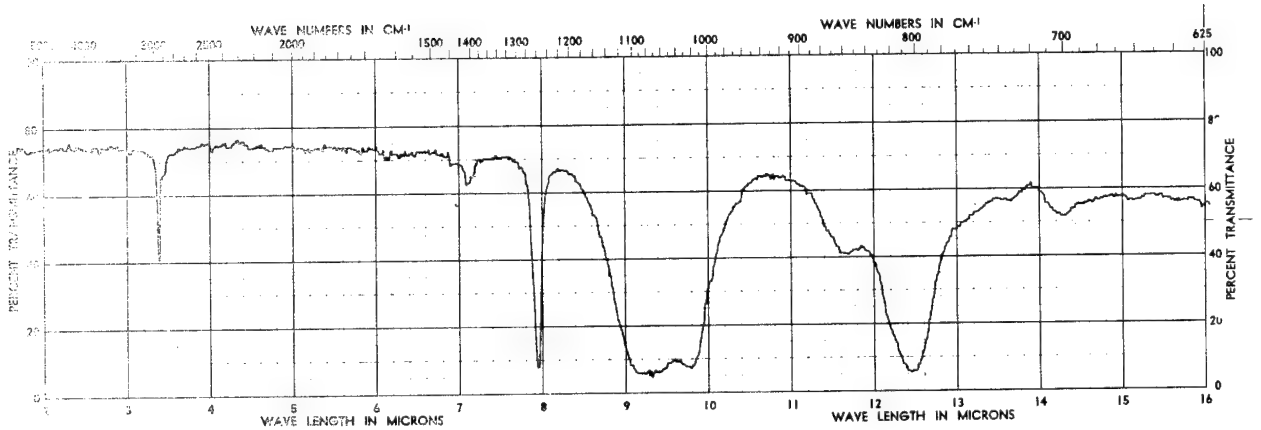


Figure 11. Silicone sealant pyrolyzate

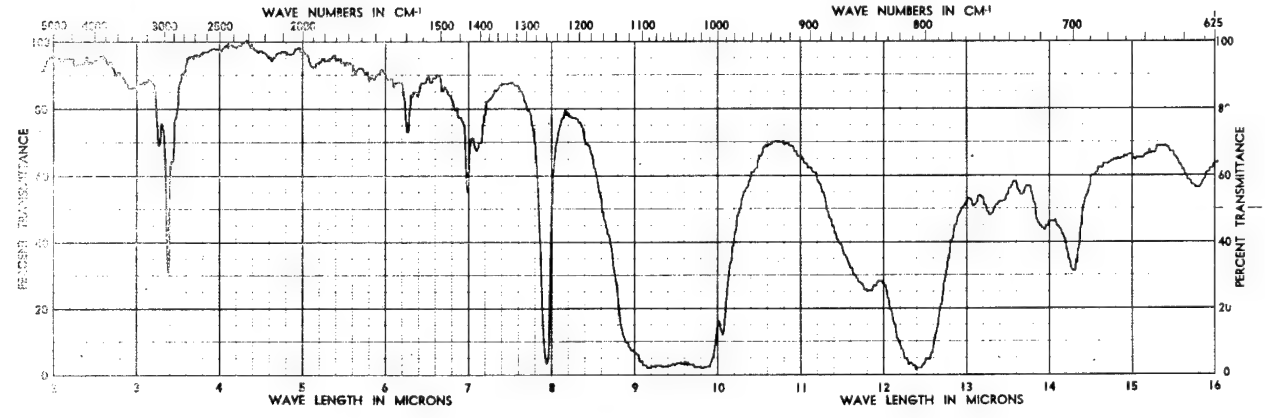


Figure 12. Silicone rubber pyrolyzate

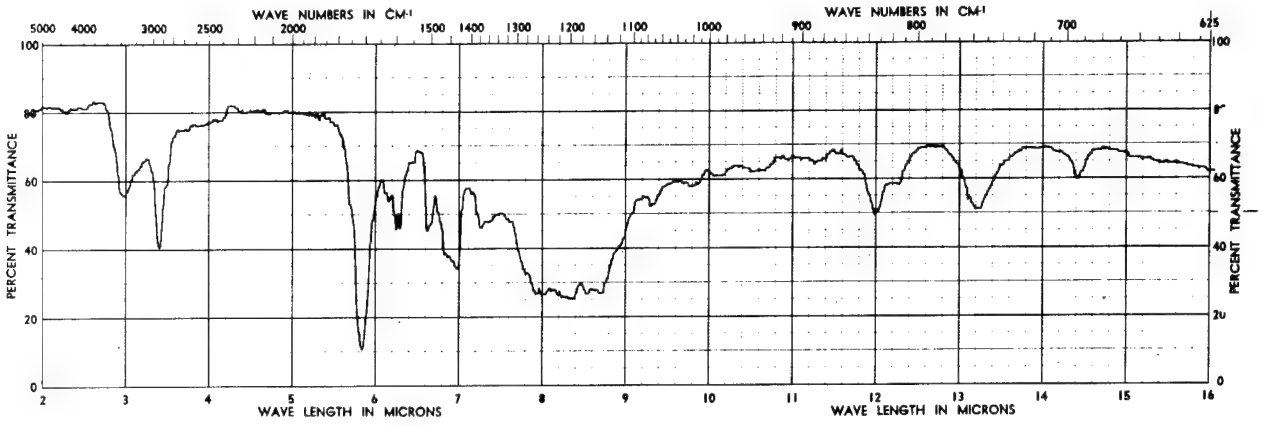


Figure 13. Methacrylate ("Lucite") pyrolyzate

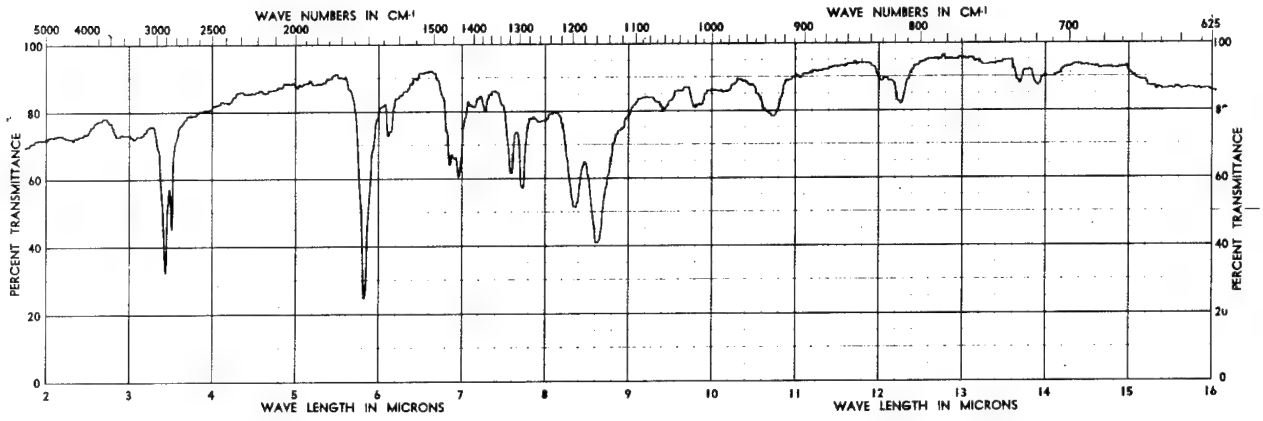


Figure 14. Methacrylate ("Transoptic") pyrolyzate

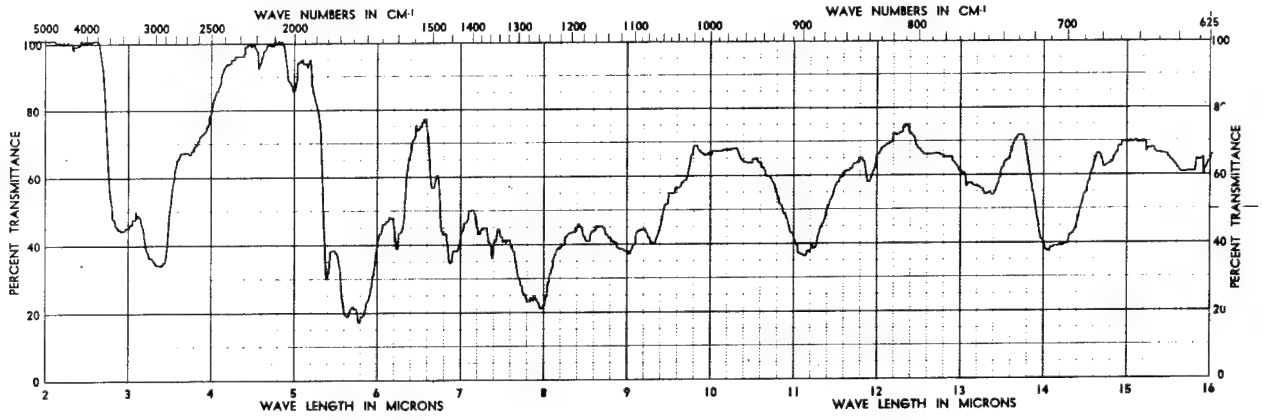


Figure 15. Polyester pyrolyzate

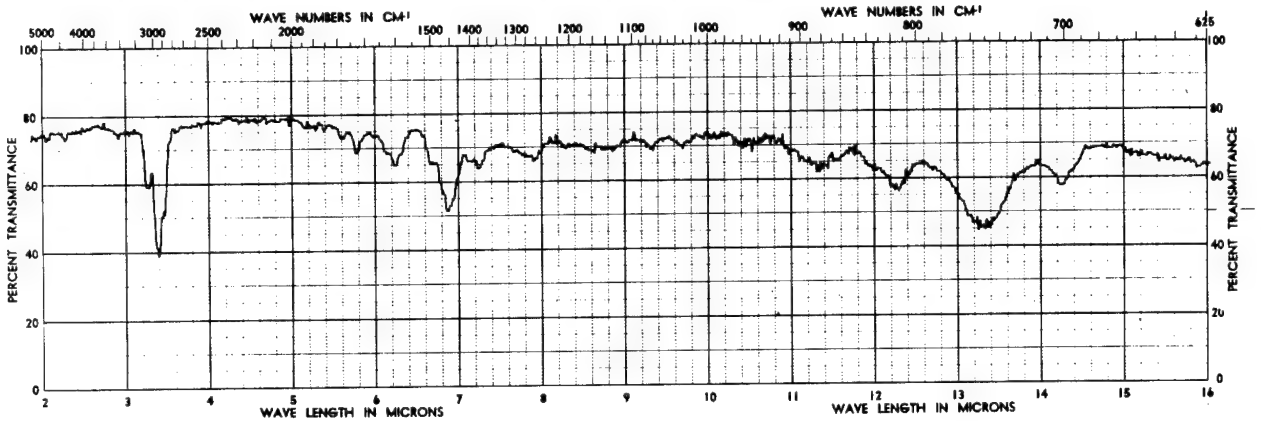


Figure 16. PVC pyrolyzate from ("Tygon") tubing extracted with methylethyl ketone and acetone

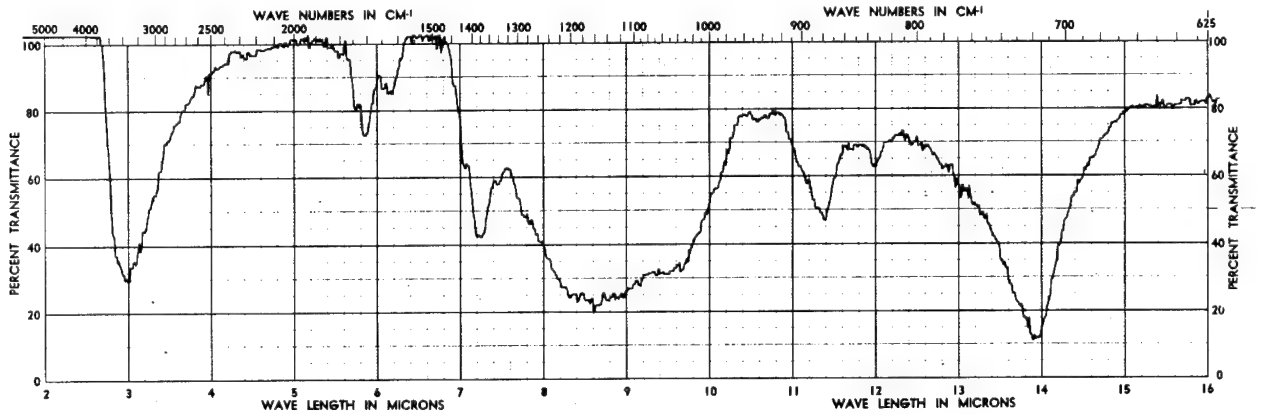


Figure 17. "Viton A" pyrolyzate

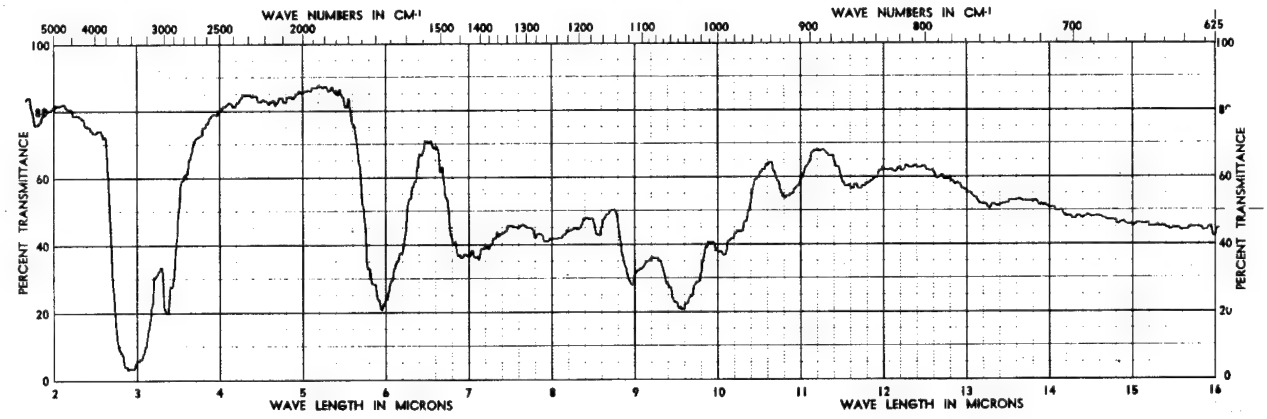


Figure 18. Polyvinyl alcohol pyrolyzate

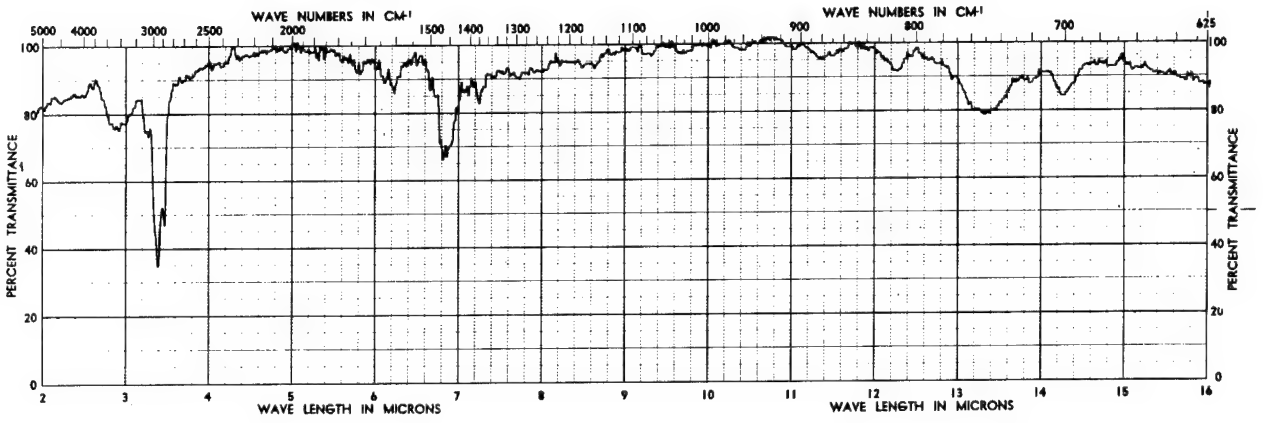


Figure 19. PVC welding rod pyrolyzate

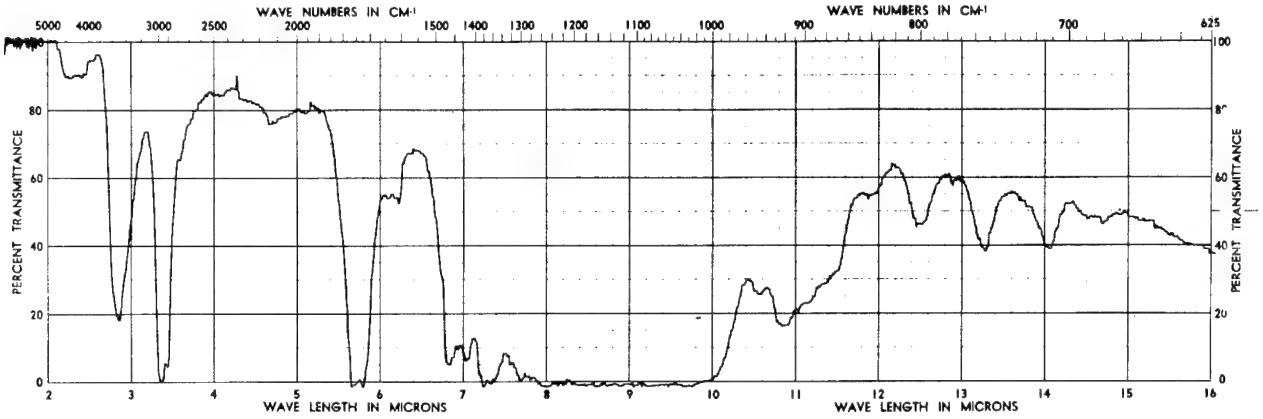


Figure 20. Cellulose acetate ("Lumarith") film - from acetone

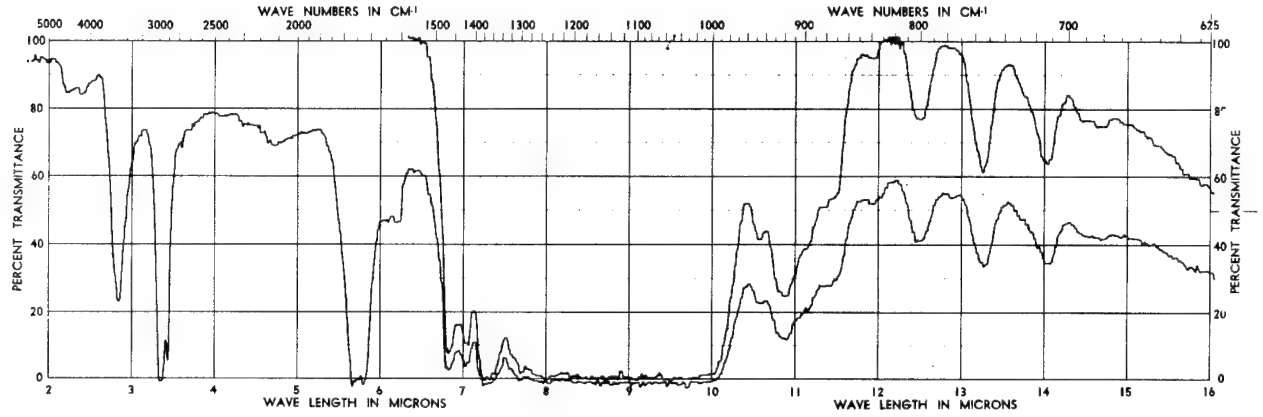


Figure 21. Cellulose acetate-butyrate ("Kodapak II") film - from acetone

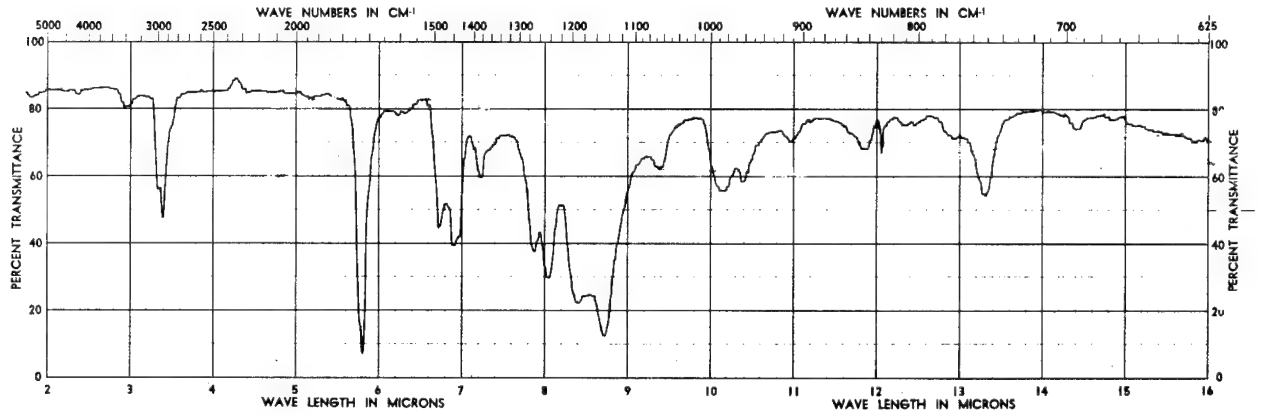


Figure 22. Methacrylate ("Lucite") film - from ethylene dichloride

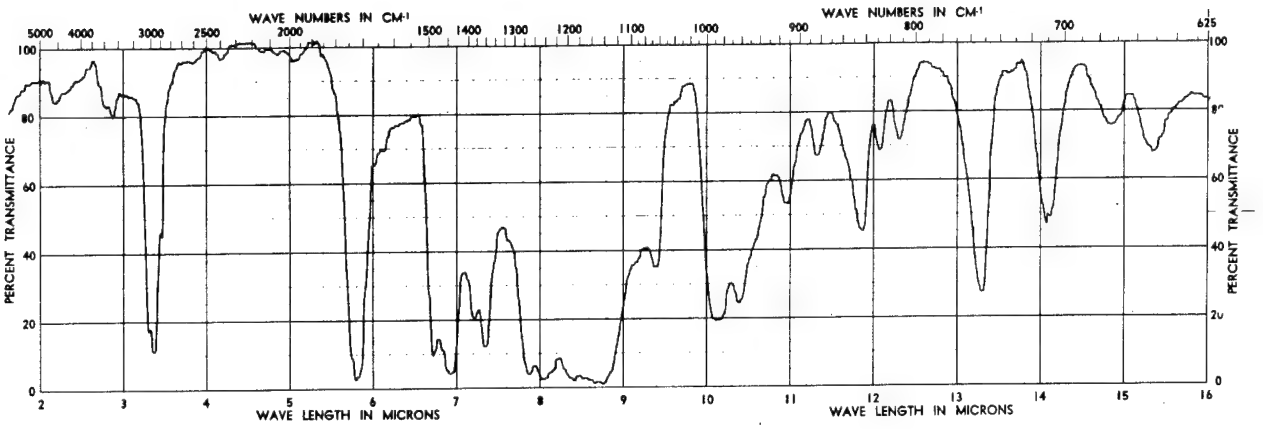


Figure 23. Methacrylate ("Transoptic") film - from ethylene dichloride

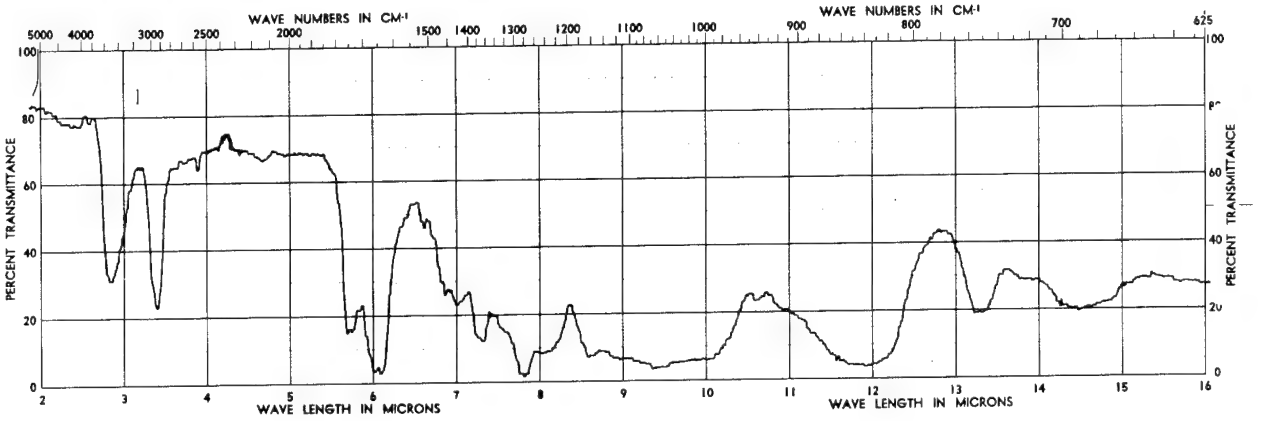


Figure 24. Nitrocellulose film - from acetone

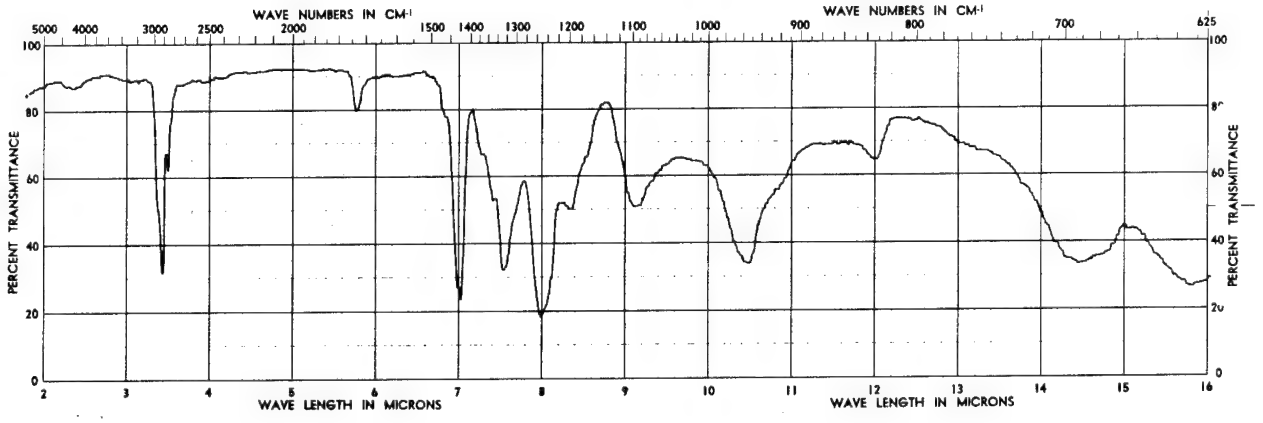


Figure 25. PVC film - from tetrahydrofuran

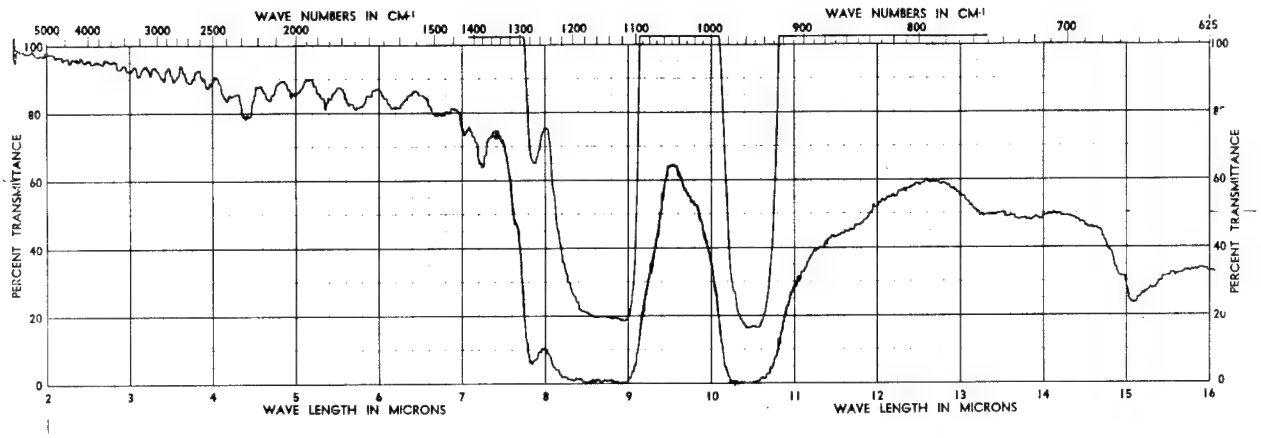


Figure 26. Fluorohalocarbon ("Aclar") - 1-mil film

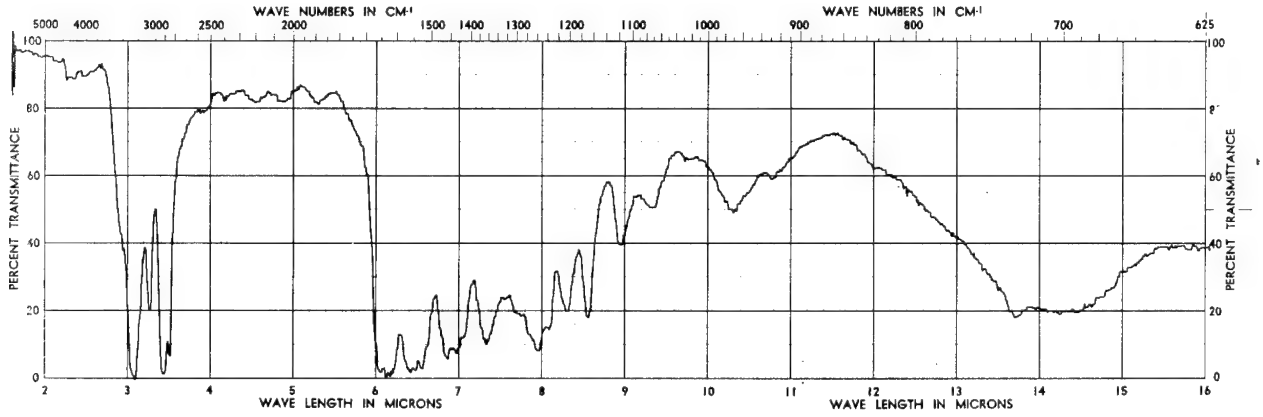


Figure 27. Polyamide ("Capran") - 1-mil film

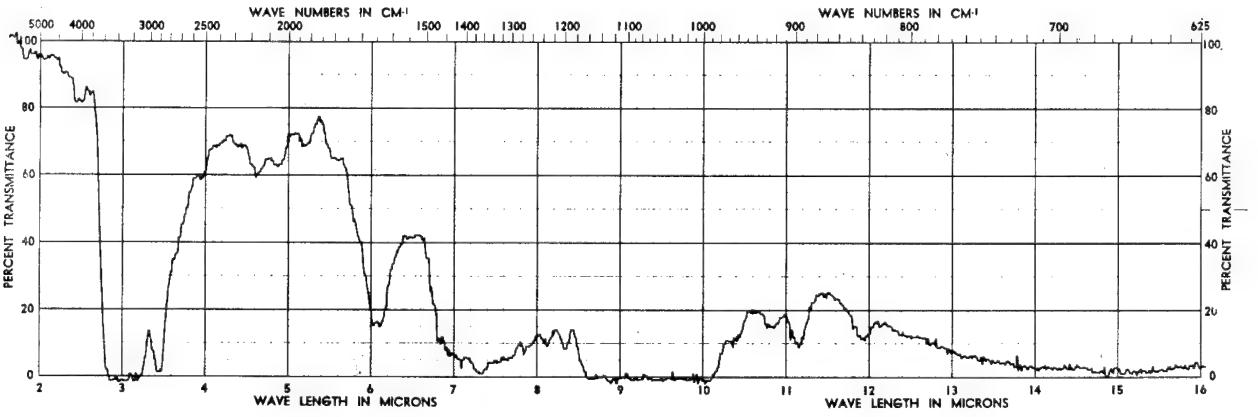


Figure 28. Cellulose ("Cellophane") - 1-1/2-mil film

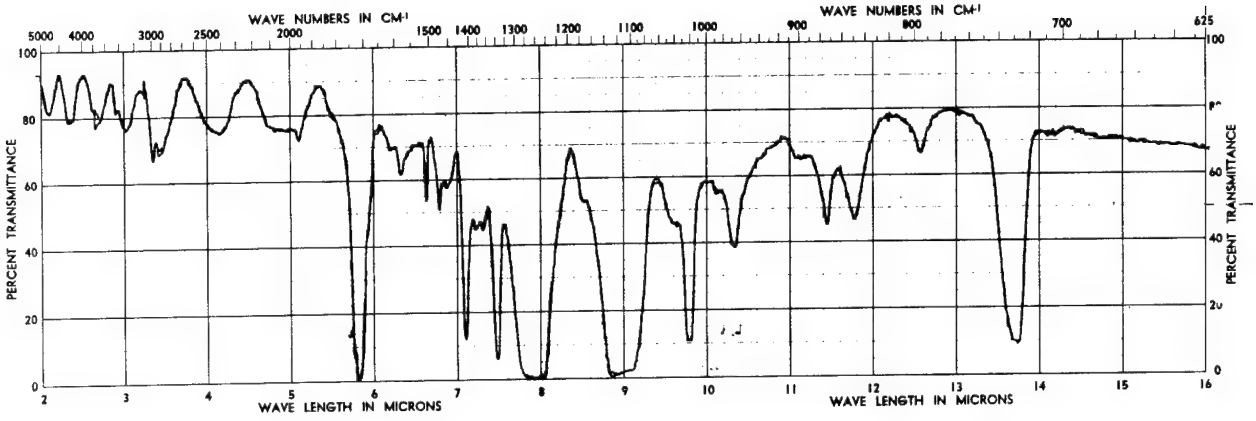


Figure 29. Polyester ("Mylar") - 1/4-mil film

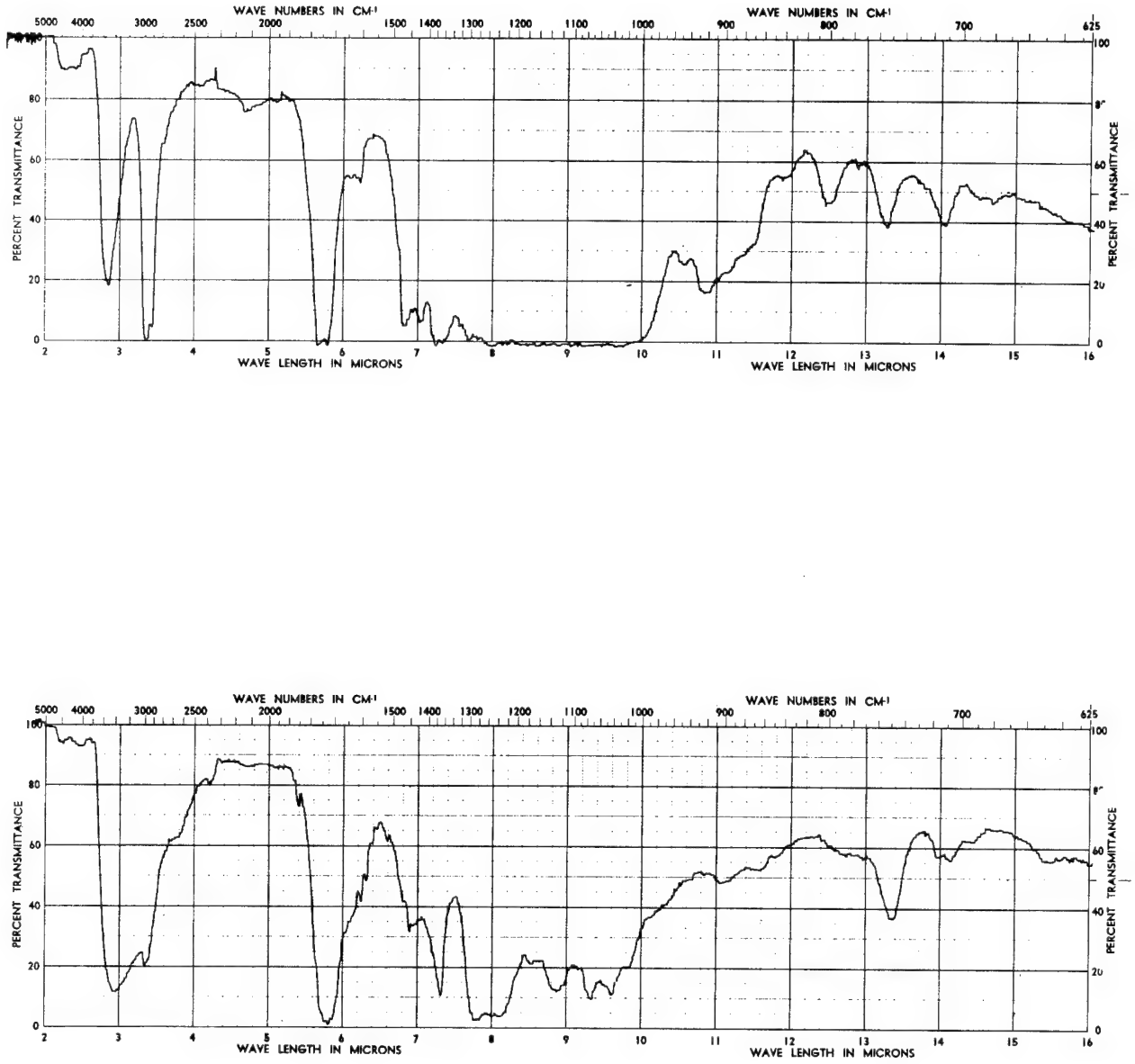
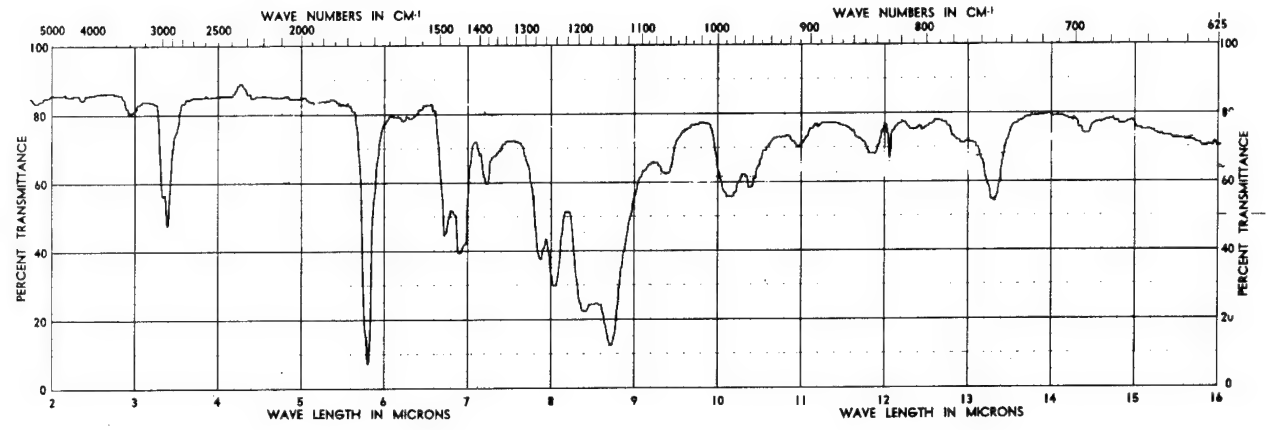


Figure 30. Cellulose acetate (upper) and its pyrolyzate (lower)



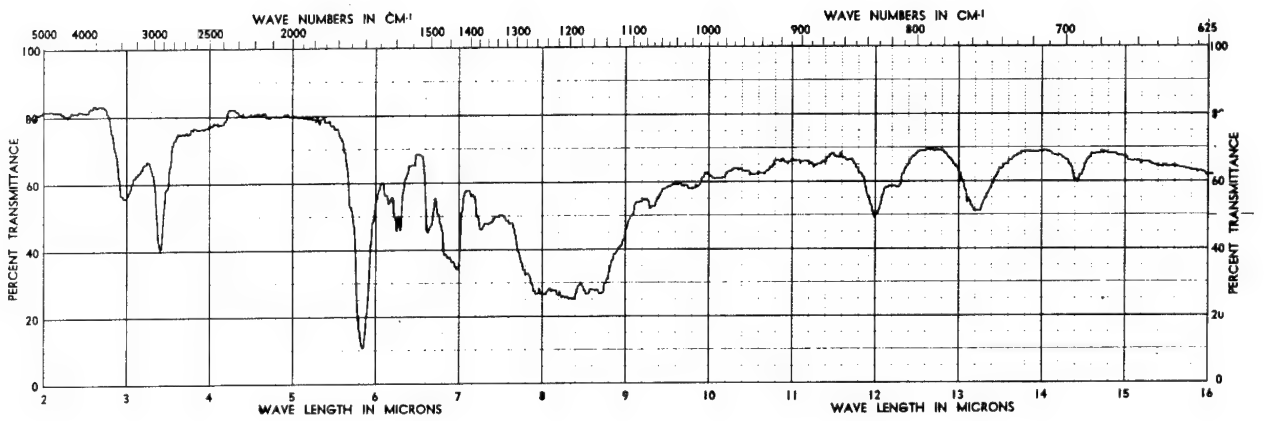


Figure 31. Lucite (upper) and its pyrolyzate (lower)

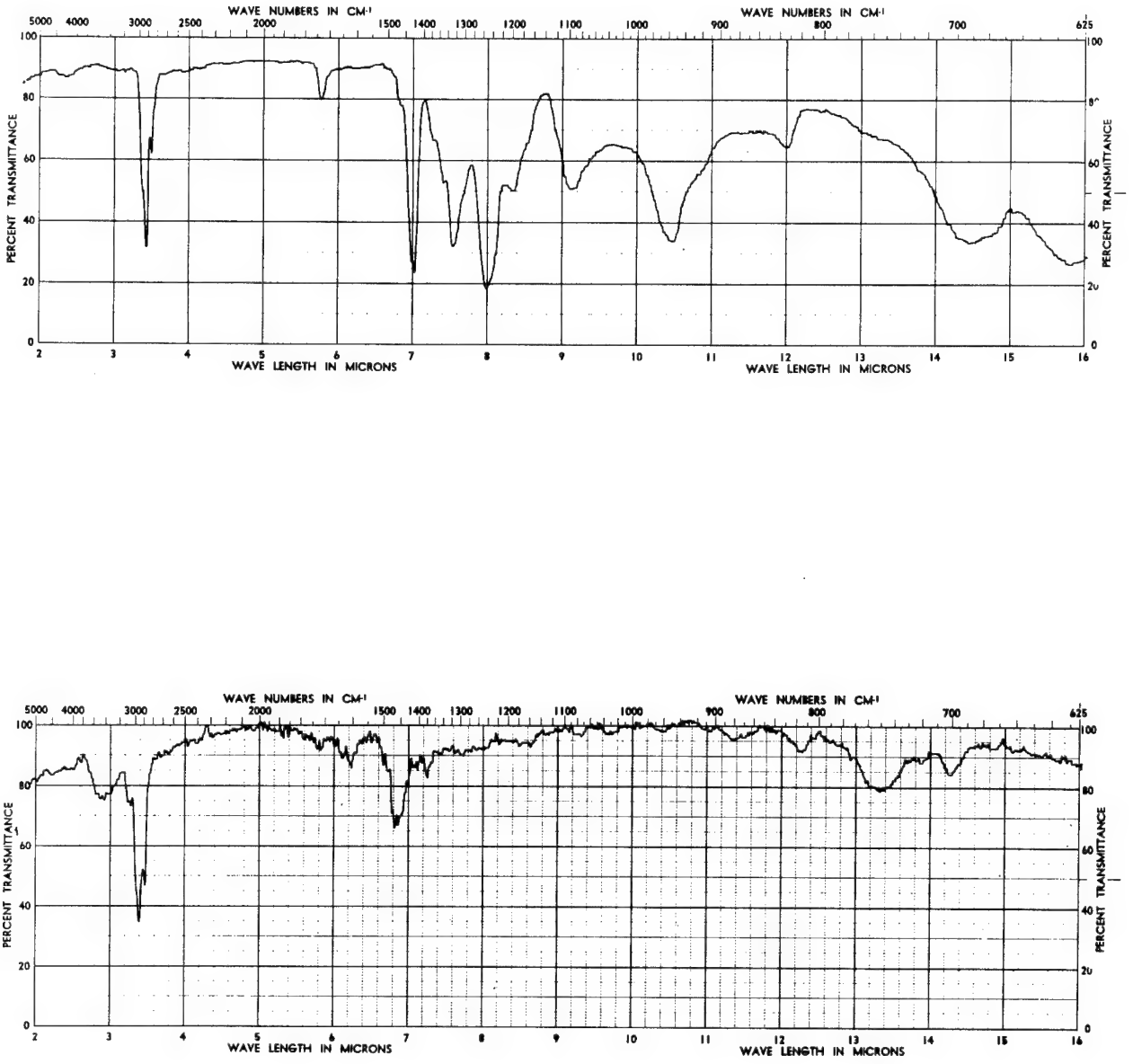


Figure 32. Polyvinyl chloride (upper) and its pyrolyzate (lower)

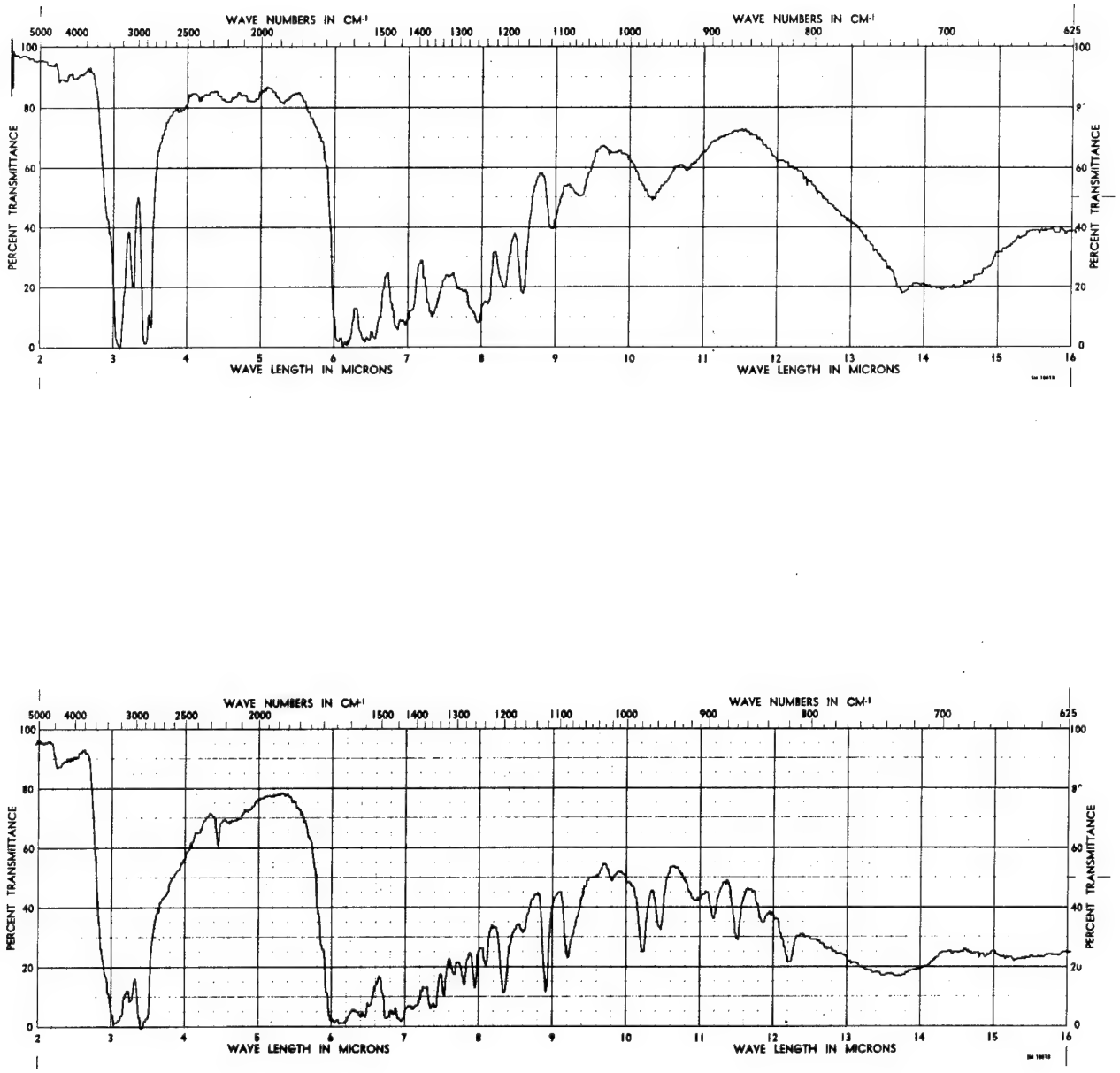


Figure 33. Capran (upper) and its pyrolyzate (lower)

APPENDIX A

LIST OF PLASTIC SAMPLES
SENT AS ENCLOSURE (1) UNDER SEPARATE COVER

No.	Name on Label	Chemical Name	Description
1.	ACETAL	ACETAL	1/4 in. white rod
2.	ACRYLIC	ACRYLIC	1 in. x 3 in. sheet (clear)
3.	ABS	ACRYLONITRILE-BUTADIENE-STYRENE COPOLYMER	2 in. sq. green plate
10.	CELLULOSE-ACETATE	CELLULOSE-ACETATE	.015 in. sheet 3 in. x 5 in.
11.	CELLULOSE ACETATE-BUTYRATE	CELLULOSE ACETATE-BUTYRATE	.015 in sheet 3 in. x 5 in.
13.	PYROXYLIN	CELLULOSE NITRATE WITH TRICRESYL PHOSPHATE	3/4 in. rod
18.	DAP	DIALLYL PHTHALATE	1-1/4 in. blue disc
20.	EPOXY R	EPOXY, AMINE HARDENED, WITH FIBER GLASS	1/2 in. x 3 in. bar
C 20.	EPOXY C	EPOXY, CAST	1-1/2 in. x 2-1/2 in. sheet (amber)
21.	ETHYL CELLULOSE	ETHYL CELLULOSE	white powder in polystyrene vial with polyethylene cap
24.	MELMAC	MELAMINE-FORMALDEHYDE	3/4 in. x 1-1/2 in. plate
26.	NYLON	POLYAMIDE, NYLON 101, 6/6	5/16 in. rod
29.	MICARTA GR 221	PHENOLIC, FABRIC BASE	1/4 in. tan rod

APPENDIX A, continued

No.	Name on Label	Chemical Name	Description
30.	PHENOLIC PAPER REIN.	PHENOLIC, PAPER BASE	2 in. tan squares
32.	PHENOLIC, MIN. FILL.	PHENOLIC, MINERAL FILLED	1-1/4 in. green disc
34.	POLYESTER, CAST	POLYESTER, CAST, UNSATURATED	3 in. x 1-1/2 in. sheet (clear)
36.	POLYESTER, GLASS REIN.	POLYESTER, FIBERGLASS REINFORCED, UNSATURATED	3 in. x 1-1/2 in. sheet
	MYLAR-A	POLYESTER, SATURATED, FILM	A-.010 in. sheet, 2 in. x 4 in.
	MYLAR-D	POLYESTER, SATURATED, FILM	D-.0075 in. sheet (clear) 2 in. x 4 in.
37.	POLYETHYLENE, LOW DENSITY	POLYETHYLENE	1/8 in. white rod
38.	POLYETHYLENE, HIGH DENSITY	POLYETHYLENE, HIGH DENSITY	1/8 in. white rod
40.	POLYPROPYLENE	POLYPROPYLENE	1/8 in. white rod
42.	STYRENE	POLYSTYRENE	clear fragments
43.	TEFLON	POLYTETRAFLUORO-ETHYLENE	3/16 in. white rod
44.	KEL-F	POLYTRIFLUOROCHLORO-ETHYLENE	1/4 in. rod (translucent)
48.	STYRENE ACRYLONITRILE	STYRENE ACRYLONITRILE	1-1/2 x 3 in. sheet
49.	UREA	UREA-FORMALDEHYDE	white granules in polystyrene vial with polyethylene cap
51.	PVA	POLYVINYL ALCOHOL	4 in. x 4 in. sheet

APPENDIX A, continued

No.	Name on Label	Chemical Name	Description
53.	PVC	POLYVINYL CHLORIDE	2 in. x 2 in. gray sheet x 1/8 in. rod
55.	SARAN	POLYVINYLIDENE-CHLORIDE	5 in. x 12 in. film .001 in. (clear)
57.	POLYCARBONATE	POLYCARBONATE	1/2 in. rod
58.	URETHANE	POLYURETHANE	tubing, 1/2 in. I.D.
59.	SILICONE	SILICONE	1/2 in. x 1-1/2 in. white sheet
60.	POLYSULFONE	POLYSULFONE	amber granules (dark) in glass vial
61.	PHENOXY	PHENOXY	amber granules (light) in glass vial
62.	PPO	POLYPHENYLENE OXIDE	1/4 in. and 3/8 in. rods
63.	NORYL	NORYL	1/4 in. and 3/8 in. rods

(1)

	PLASTIC MATERIAL	EASE OF IGNITION	SELF EXTINGUISHING	CHARACTER OF FLAM
1.	Acetal	Moderate	No	Clean blue flame; no smoke -
2.	Acrylic	Readily	No	Yellow top, blue around bott edges; some black smoke; spu
3.	Acrylonitrile-butadiene-styrene polymer blend	Readily	No	Yellow; black smoke
4.	Alkyd (mineral filled)	Difficult	Yes	Yellow
5.	Allyl ester	Moderate	No	Yellow, blue edges; black sm
6.	Aniline formaldehyde	Readily	Yes	Yellow; large spurts; black smoke
7.	Butadiene copolymer rubber	Readily	No	Dark yellow; smoky; clumps o carbon in the air
8.	Butyl rubber	Readily	No	Yellow; black smoke
9.	Casein	Moderate	Yes	Yellow: grey smoke
10.	Cellulose acetate	Readily	No	Dark yellow; some sooty blac smoke
11.	Cellulose acetate butyrate	Readily to moderate	No	Dark yellow with slight blue edges; some black smoke (not sooty)
12.	Cellulose acetate propionate	Readily	No	Dark yellow; some black smok
13.	Cellulose nitrate	Very readily	No, burns extremely fast	Yellows; very hot
14.	Cellulose propionate	Readily	No	Dark yellow; some black smok
15.	Chlorinated polyether	Difficult	Yes	Sputtering, bottom green, to yellow; dense black smoke; c of carbon in the air
16.	Cold molded (bitumious)	Very difficult	Yes	Yellow; may give off black s
17.	Cold molded (phenolic or melamine bond)	Will not burn	---	---
18.	Diallyl phthalate	90 sec. (Mil M-14 E)	Yes	Yellow; black smoke

(2)

QE/K 67-83

APPENDIX B - BURNING CHART

(REPRINTED FROM MODERN PLASTICS ENCYCLOPEDIA ISSUE FOR 1960, VOLUME 37 NUMBER 1A, BRISTOL, CONNECTICUT, MCGRAW-HILL, INC., SEPTEMBER 1959, BY PERMISSION OF MCGRAW-HILL, INC.)

CHARACTER OF FLAME	BEHAVIOR OF MATERIAL	ODOR
flame; no smoke -------	Melts; drips; drippings continue to burn -	None while burning; formaldehyde on extinguishing
, blue around bottom --- e black smoke; spurts	Softens; usually no drip; very little char left after flame is blown out ---	Characteristic, acrylic monomers (fruity)
ack smoke ----------	Softens and chars ----------	Characteristic
----------	Chars, cracks ----------	Characteristic, polyesters
ue edges; black smoke----	Cracks and pieces fall off; fallen pieces continue to burn; turns yellow, small amount of melted material at edges of burned area ------	Characteristic, allyl resins
rge spurts; black ------	Swells; softens ----------	Characteristic, formaldehyde
w; smoky; clumps of ---- the air	Softens ----------	Characteristic
ack smoke ----------	Softens; cracks ----------	Characteristic (medicinal)
ey smoke ----------	Swells; chars ----------	Burning protein materials, e.g. wool, milk curds, silk, etc.
w; some sooty black ----	Melts; drips; drippings continue to burn ----------	Characteristic (burnt sugar)
w with slight blue ----- e black smoke (not	Melts; drips; drippings continue to burn ----------	Characteristic; butyric acid; (rancid butter)
w; some black smoke ----	Melts; drips; drippings continue to burn ----------	Characteristic; propionic acid
ery hot ----------	Material burns completely --------	Burns too fast to detect
w; some black smoke ----	Melts; drips; drippings continue to burn ----------	Characteristic; propionic acid
, bottom green, top ---- ise black smoke; clumps in the air	Softens, no drip ----------	Characteristic
y give off black smoke -	Chars ----------	Bituminous; waxy odor
----------	----------	----------
ack smoke ----------	Softens ----------	Characteristic

(1)

	PLASTIC MATERIAL	EASE OF IGNITION	SELF EXTINGUISHING	CHARACTER OF FLAM
19.	Epoxy, phthalic anhydride hardened	Readily	No	Yellow, spurts black smok
20.	Epoxy, amine hardened	Readily	No	Yellow, spurts heavy blac
21.	Ethyl cellulose	Readily	No	Yellow, blue edges
22.	Lignin, laminated paper	Moderate	No	Dark yellow; black smoke; purple edge on flame
23.	Lignocellulose	Moderate to difficult	Yes	Yellow; purplish blue aro bottom; spurts
24.	Melamine-formaldehyde	Difficult	Yes	Light yellow
25.	Neoprene	Readily	Yes, slow	Orange-yellow; black smok green section around bott
26.	Nylon	Moderate	Yes	Blue with yellow top
27.	Phenolic, cast	Difficult to Moderate	Yes	Yellow; sparks
28.	Phenolic - impregnated wood	Moderate	Yes, but continues to burn for a few minutes after removal from flame	Yellow
29.	Phenolic, laminated, fabric base	Moderate	No	Yellow; a little black sm
30.	Phenolic, laminated, paper base	Moderate	No	Yellow; a little black sm
31.	Phenolic, laminated, asbestos	Difficult	Yes	Yellow
32.	Phenolic, molded, filler	Difficult	Yes	Yellow
33.	Phenolic, molded, no filler	Very difficult	Yes	Yellow; sparks less than
34.	Polyester, cast	Readily	No	Yellow; black
35.	Polyester, standard unfilled	Moderate	No	Yellow; black smoke, burn steadily
36.	Polyester-glass mat laminate	Difficult	No	Yellow; some soot
37.	Polyethylene	Readily	No	Bottom blue, top yellow -
38.	Polyethylene (high - density)	Readily to Moderate	No	Bottom blue, top yellow; white smoke
39.	Polyethylene (filled)	Difficult	Yes	Yellow with slight smoke

(2)

APPENDIX B - BURNING CHART (Cont)

ACTER OF FLAME	BEHAVIOR OF MATERIAL	ODOR
s black smoke -------	Melts at edge; chars ----------	Characteristic
s heavy black smoke -	Chars ----------	Characteristic
edges ----------	Melts; drips; drippings continue - to burn	Characteristic; resembles cellulose acetates, except LT composition which resembles burning oil and wax
black smoke; light -- n flame	Swells; cracks between laminae; - softens	Resembles burning wood
ish blue around ----- s	Swells, cracks ----------	Resembles burning wood, may be slightly sweet
----------	Swells, cracks; turns white at --- edges of burned section	Characteristic penetrating odor; resembles urea; ammonia and formaldehyde present
; black smoke; small- around bottom	Softens, char remains ----------	Characteristic, slight resemblance to natural rubber, sharp component present
low top ----------	Melts, drips, and froths ---------	Characteristic (burning proteins)
s ----------	Cracks badly and deeply ----------	Phenolic, strong with formaldehyde
----------	Swells; cracks ----------	Wood; phenolic
tle black smoke -----	Swells; cracks between laminae; -- cloth continues to glow	Fabric; phenolic
tle black smoke -----	Swells; cracks between laminae ---	Paper; phenolic
----------	Surface cracks (blisters) -------- and oxidizes	Phenolic; formaldehyde
----------	Swells, cracks; (wood-filled ----- blisters and has afterglow and white ash)	Phenolic; odor from resin may be temporarily marked by odor from decomposing organic fillers such as woodflour, e.g. burnt wood
s less than cast ----	Cracks ----------	Phenolic
----------	Melts at edges ----------	Characteristic, polyester
smoke, burns -------	No drip or falling particles; ---- softens; burns steadily	Characteristic (slightly bituminous)
soot ----------	Chars ----------	Characteristic
top yellow ----------	Melts and drips ----------	Burning paraffin
top yellow; ---------	Melts and drips ----------	Burning paraffin
light smoke ---------	Softens, char remains ----------	Burning paraffin

(1)

	PLASTIC MATERIAL	EASE OF IGNITION	SELF EXTINGUISHING	CHARACTER OF FLAME
40.	Polypropylene	Readily to Moderate (depending on thickness)	No	Bottom blue; top yellow; s white smoke
41.	Polymethylstyrene	Readily	No	Similar to polystyrene
42.	Polystyrene	Readily	No	Orange-yellow; black dense smoke; large clumps of carbon in the air
43.	Polytetrafluoro-ethylene	Will not ignite in Bunsen flame	Yes	Yellow, green near base
44.	Polytrifluorochloro-ethylene	Does not ignite		
45.	Rubber, hard, natural	Readily	No	Orange-yellow; black smoke spurts or shoots of light yellow flame
46.	Rubber, natural	Readily	No	Dark yellow; black smoke
47.	Shellac	Easily	No	Orange-yellow; blue around bottom edges; black smoke; a few blue-light yellow sp
48.	Styrene-acrylonitrile copolymer	Readily	No	Yellow; heavy black smoke
49.	Urea-formaldehyde	Difficult	Yes	Pale yellow with light greenish-blue edge
50.	Vinyl acetate	Readily	No	Dark yellow flame; spurts, smoke; clumps of carbon sm than that from polystyrene
51.	Vinyl alcohol compound	Readily	No	Yellow; black smoke
52.	Vinyl butyral	Readily	No	Bottom blue, top yellow
53.	Vinyl chloride	Difficult	Yes	Yellow, green on bottom ed spurts green and yellow; w smoke
54.	Vinyl chloride-acetate	Difficult to moderate	Yes	Dark yellow; smoky; green edges
55.	Vinylidene chloride	Very difficult	Yes	Yellow, green on edges; sp green
56.	Vulcanized fibre	Moderate	No	Light yellow; purple edges
57.	Polycarbonate	Difficult	Goes out slowly	Yellow; some black smoke
58.	Polyurethane	Readily	No	Yellow; spurts black smoke
59.	Silicone	Moderate	No	Small yellow, white smoke
60.	Polysulfones	Moderate	Yes	Yellow, black sooty smoke
61.	Phenoxy *	Easily	Burns slowly	Yellow-orange black smoke
62.	Polyphenylene Oxide	Moderate	Yes	Yellow, black sooty smoke
63.	Noryl	Moderate	Yes	Yellow, black sooty smoke

*PRDA - 8060 tested; PRDA - 8160 is self-extinguishing and non-dripping according to manufacturer

APPENDIX B - BURNING CHART (Cont)

TER OF FLAME	BEHAVIOR OF MATERIAL	ODOR
ɔp yellow; some ----	Melts and drips ----------	Burning paraffin
ɣstyrene ----------	Softens ----------	Characteristic, methylstyrene monomer
black dense -------	Softens, bubbles ----------	Characteristic, styrene monomer
lumps of air		
ıear base ----------	Melts, bubbles, slight ---------- charring	Very little odor
----------	Softens ----------	Characteristic
black smoke; ------ ts of light	Swells, material does not soften, but liquid comes to surface --------	Characteristic
lack smoke ---------	Softens ----------	Characteristic
blue around -------	Softens ----------	Characteristic (sealing wax)
ɔlack smoke; ıt yellow spurts		
ɔlack smoke --------	Melts; bubbles; chars more than polystyrene -------	Characteristic, polyacrylonitrile
th light ---------- edge	Swells; cracks; turns white at edges of burned section ---	Characteristic; urea; strong with formaldehyde; (strong pancake odor)
ame; spurts, black - ɔf carbon smaller polystyrene	Softens ----------	Characteristic; resembles other vinyls except for absence of chlorine; resembles polystyrene
smoke -------------	Softens; spatters; blisters ------	Characteristic, resembles vinyl
ɔp yellow ----------	Melts and drips; drippings usually do not continue to burn -------	Characteristic, resembles vinyl and butyric acid
ɔn bottom edges; --- ıd yellow; white	Softens ----------	Characteristic; chlorine
noky; green at -----	Softens; chars; bubbles ----------	Characteristic; hydrochloric acid detectable
ɔn edges; spurts ---	Softens; chars; leaves ash -------	Characteristic; chlorine
ɔurple edges -------	Swells at edges; splits on laminae; smolders -------	Burning hay or grass
lack smoke ---------	Melts, bubbles and chars ---------	Weak, characteristic
black smoke -------	Melts and drips, turns dark brown -	Acrid
white smoke --------	Swells, cracks, turns white, ash glows -----	Very little odor
sooty smoke --------	Melts, drips, black ash ----------	Characteristic
black smoke sparks -	Melts sharply and drips ----------	Characteristic
sooty smoke --------	Non-dripping, black ash ----------	Characteristic (ether like)
sooty smoke --------	Non-dripping, black ash ----------	Characteristic

nanufacturer

APPENDIX C

LIST OF RECOMMENDED READING

Coakley, J.E., and Berry, H.H., "Pressed Film Technique for Obtaining Infrared Spectra of Thermoplastic Materials," Applied Spectroscopy, Volume 20 Number 6, November-December 1966
Saunders, K.J., The Identification of Plastics and Rubbers, London, England, Chapman and Hall Ltd, 1966.

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Infrared Spectroscopy Its Use as an Analytical Tool in the Field of Paints and Coatings, paper presented by Infrared Spectroscopy Committee of the Chicago Society for Paint Technology at the 38th Annual Meeting of the Federation of Societies for Paint Technology, Chicago, Ill., October 1960.

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13. ABSTRACT

Tests are described for identifying plastics found in Naval ordnance weapons. The tests require relatively simple procedures and equipment. Identification tests described are sensory, burning, chemical, and infrared spectroscopic tests. Typical spectrograms are included (U).

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Identification						
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